Supplementary material folder 2 (BJSM)

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Risk factors for the development of primary cam morphology: a systematic review and meta-analysis (Dijkstra et al, unpublished)

Eligibility criteria

We included articles if they:

- Included ≥ 10 human participants of any age

- reported cam morphology, or the development of cam morphology as an outcome measure (reported in the literature in a variety of ways, including alpha angle (dichotomous or continuous - mean or median), femoral head ratio (FHR), tilt deformity, pistol grip or femoro-acetabular impingement). We also included studies using offset measurements.

- examined at least one aetiological risk factors for the development of primary / idiopathic cam morphology (prospective and retrospective cohort studies, cross sectional studies, and case control studies), randomised trials or controlled (non-randomised) clinical trials (in which the evaluated intervention might be an aetiological risk factor or because other risk factors are measured inside an evaluation of other interventions).

We excluded qualitative studies and case-series (e.g. surgical or imaging case series) as well as studies investigating the aetiology of secondary cam morphology, also referred to as 'developmental deformities' (e.g. dysplasia, Legg-Calve-Perthes disease, osteonecrosis, posttraumatic arthritis,

slipped capital femoral epiphysis, inflammatory arthritis) and studies designed to investigate cam morphology as a prognostic risk factor for the development of hip joint osteoarthritis.

Search strategy

We performed a literature search of 11 databases from date of inception to 21st May 2018 after agreeing on a search strategy. The databases searched were: AMED (OvidSP)[1985-2018], CINAHL (EBSCOHost)[1982-2018], Cochrane Central Register of Controlled Trials (Cochrane Library, Wiley)[Issue 4 of 12, April 2018], Embase (OvidSP)[1974-2018], Medline(OvidSP)[1946-2018], PEDro (http://www.pedro.org.au), PubMed (EPub ahead of print and Non-Medline) (https://pmlegacy.ncbi.nlm.nih.gov/ - legacy version available to October 2020), Science Citation Index & Conference Proceedings Citation Index – Science (Web of Science Core Collection)[1945-2018], SCOPUS (http://www.scopus.com) and SPORTDiscus (EBSCOHost). The search strategy included free-text terms and subject headings related to cam morphology and femoroacetabular impingement as well as a risk factor-specific terminology, no date or language limits were applied. We also looked at the reference list of included articles for other potentially relevant articles. We provide the Medline search strategy in table 1.

Table 1	Medline search strategy
1	Femoracetabular Impingement/
2	((hip or hip joint or femur* or femoral or femoroacetabular or femoracetabular or femoro-acetabular or femor-acetabular or acetabular or acetabulum or pincer or cam) adj5 impinge*).ti,ab.
3	((hip or hip joint or femur* or femoral or femoroacetabular or femoracetabular or femoro-acetabular or femor-acetabular or acetabular or acetabulum or pincer or cam) adj3 abnormal*).ti,ab.
4	((hip or hip joint or femur* or femoral or femoroacetabular or femoracetabular or femoro-acetabular or femor-acetabular or acetabular or acetabulum or pincer or cam) adj3 deform*).ti,ab.
5	((hip or hip joint or femur* or femoral or femoroacetabular or femoracetabular or femoro-acetabular or femor-acetabular or acetabular or acetabulum or pincer or cam) adj3 malform*).ti,ab.
6	1 or 2 or 3 or 4 or 5
7	risk*.mp. or exp cohort studies/ or between group*.tw.
8	6 and 7
9	6 not 7

Study selection

Two researchers (HPD and CA) independently reviewed the titles and abstracts. We obtained full texts for all the records with insufficient detail to determine eligibility as well as those meeting the inclusion criteria on the basis of the title and abstract. The two researchers (HPD and CA) independently reviewed 266 full texts.

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Disagreements at both the title/abstract and full text screening stages were resolved by discussion between the reviewers and, if needed, in consultation with a third reviewer (AM).

Data extraction

Data extraction was done independently by two researchers: HPD extracted data from all 111 papers and papers were randomly allocated to one of three second reviewers (CA, AS, AW) for extraction. We used Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia; available at www.covidence.org) to extract data in 4 domains (table 2 appendix). Each independent extraction was followed by a consensus discussion between HPD and the second reviewer.

Table 2 Data extraction domains adapted from the CHARMS Checklist [1]	
Domain	**Description**
Source of data (e.g., cohort, case-control, randomised trial)	Data items: title, first author, year of publication, publication journal, funding source and conflict of interest, study code designation, study design (prospective, retrospective), study characteristics (end point definition, study period, sample size, control conditions, interventions / exposures, randomization, blinding of presence/absence of risk factor during diagnosis of cam morphology
Participants	1. study population and patient demographics (sex ratio, age range, race and ethnicity) 2. number of participants and number of outcomes 3. number of outcomes in relation to the presence/absence of the risk factor
Risk factors for cam morphology	We considered all factors that have been investigated as potential aetiological risk factors. 1. Demographic (race, ethnicity, age, sex, BMI, education level, economic status) 2. Lifestyle/environment (diet, sport – type & volume, age when competitive sport practice started) 3. Other
Methodology for defining cam morphology	1. Definition 2. Method of measurement of cam morphology (alpha-angle, reduced hip internal rotation, FAI) 3. Radiological measurement method; how and in what position was the cam morphology/alpha angle measured 4. Outcome definition used and consistency of methodology within and between studies? 5. Whether cam morphology prevalence was reported per hip or per individual 6. Type of outcome (single or combined endpoints) 7. Blinding for predictors of the outcome assessed 8. Frequencies, effect estimates and confidence intervals for: follow-up period, number of patients lost to follow-up, number of cases, identified risk factors, adjusted effect estimates and 95% CI.

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Quality and risk of bias assessment

We evaluated the quality of included articles by combining the Quality in Prognosis Studies (QUIPS) tool [2,3] and Risk of Bias tool for Non-randomised Studies (RoBANS) [4] in the following 6 domains: selection of participants, confounding, exposure measurement, outcome measurement (definition, blinding, method and setting), outcome data (attrition), and reporting. Quality evaluation was done independently by two researchers: HPD reported risk of bias in each domain as high, unclear or low risk of bias for all 111 papers. Papers were randomly allocated to one of three second reviewers (CA, AS, AW) for independent risk of bias assessment. We used Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia; available at www.covidence.org). Disagreements were resolved by consensus discussion, involving a third author AM, if needed.

Data synthesis and analysis

We performed a qualitative thematic concept analysis of the terminology and conceptual and operational definitions used for primary cam morphology.

We will report the quantitative and qualitative risk factor analyses in a separate paper.

Terminologies related to cam morphology used in 111 included papers

FAI; FAI syndrome; FAI deformity; cam FAI; cam-FAI; cam-only FAI; cam-type FAI; cam type FAI; FAI of cam type; cam-type FAI deformity; cam-type FAI deformities; cam (as subtype of FAI); combined ("cam" and "pincer") FAI; mixed pincer-cam aetiology; mixed FAI; cam or mixed FAI; FAI abnormalities; FAI impingement; cam impingement FAI; 'acetibular' impingement; femoroacetabular impingement (FAI); femoro-acetabular impingement; cam femoro-acetabular impingement; cam type femoro-acetabular impingement; hip joint cam femoro-acetabular impingement; morphological hip joint cam type femoro-acetabular impingement; morphological characateristics of hip joint FAI; cam femoroacetabular impingement; cam-type femoroacetabular impingement; cam-type anterior femoroacetibular impingement; femoroacetabular impingement morphology; femoroacetabular impingement syndrome; deformities associated with femoroacetabular impingement; cam femoroacetabular impingement; cam-type femoroacetabular impingement; qualitative cam-type findings; cam-type findings; FAI morphology; FAI morphology type; cam FAI morphologies; morphological abnormalities; increased morphological cam deformity; morphological hip joint cam deformity; hip joint cam deformities; mechanical abnormalities; pistol grip morphologic features; pistol grip deformity; pistol-grip deformity; PGD; pistol grip malformation; symptomatic / asymptomatic FAI; symptomatic femoroacetibular impingement; symptomatic FAI; asymptomatic morphological FAI; FAI-type morphologies; cam; cams; cam combined; cam morphologic features; cam-type morphologic features; cam-type morphology; cam-type morphologies; cam morphology; large cam morphology; large cam deformity; abnormal morphology; cam and pincer morphology; symptomatic and asymptomatic cam morphology; symptomatic and asymptomatic cam deformities; symptomatic cam-type deformities; symptomatic cam-type impingement; symptomatic cam-type femoroacetabular impingement (FAI); symptomatic cam; symptomatic cam-type FAI; asymptomatic cam-type deformities; asymptomatic cam; cam parameters; cam region; cam severity; cam size; cam-angle; cam-effect; cam-rad; cam-width; cam shapes; cam-shaped abnormality; cam abnormalities; cam pathology; cam-type pathology; pathological cam-type morphology; cam-type pathomorphology; cam type; Cam-type; cam-type abnormality; Cam-type deformity; Cam-type

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deformity (FAI); cam-type deformities; cam deformity; cam-deformity; cam deformities; cam-like deformities; cam-type femoral deformity; deformity; severe deformity; tilt deformity; anatomical deformity; cam-defect; pathological cam deformity (alpha angle > 78°); abnormal alpha angle; pathological deformity; impingement angle (<70° = pathologic); contour deformity; cam features; Cam-type feature; Cam-type features; cam-type hips; cam hips; cam hip; young cam hips; The cam; cam resection; cam-type impingement; cam type impingement; hip deformity of the cam type; cam impingement; symptomatic cam impingement; symptomatic cam or mixed type FAI; cam impingement patients; cam impingement hips; cam acetabulum; radiological cam impingement; radiographic cam FAI; radiographic cam FAI deformity; cam FAI deformity; radiographic FAI; cam radiographic deformity; radiographic cam deformity; radiographic cam-type deformity; cam-type radiographic features; radial cam; lesion; cam-type lesion; cam type lesion; cam lesion; cam lesions; cam-type lesions; cam formation; cam patients; cam-only patients; cam group; non cam group; non cam cases; hip morphology; hip joint morphology; abnormal joint morphology; bony morphology of the hip joint; structural hip deformities; alterations in hip morphology; cam hip morphology; cam-positive; cam-positive hips; femoral morphology; non-spherical shape of the femoral head; non-spherical head; nonspherical head; nonspherical morphologic features; nonspherical femoral head; non-spherical femoral head; aspherical femoral head; asphericity of the femoral head; asphericity of the lateral femoral head; head-neck asphericity; femoral head asphericity; decreased sphericity of the femoral head; decreased femoral offset; femoral head-neck morphology; femoral head-neck type; anterior impingement (of the femoral neck on the acetabulum); bone overgrowth on the femoral head and neck; abnormalities of the femoral head-neck junction; femoral head-neck junction deformity; femoral head-neck junction concavity; anatomy of the femoral head-neck junction; pathological cam-type head-neck junction; decreased head-neck offset; head-neck offset; abnormalities of the femoral head; femoral and acetibular abnormalities; bony deformity on the femoral head; bony morphology; bony morphology of the hip; hip bony morphology; bony hip morphology; bony hip morphological abnormalities; abnormal bony morphology; flattening of the femoral head-neck offset; osseous bump at the femoral head-neck junction; osseous bump; osseous (cam) bump; bump; bump at the femoral head-neck junction; cam femoral surfaces; cam femur; femoral cam; proximal femoral cam lesion; proximal femoral morphology; proximal femoral cam deformity; femoral lesion; 'femoroacetibular' lesion; coxa recta

References

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